AD-A095 518 WASHINGTON UNIV SEATTLE APPLIED PHYSICS LAB F/G 8/3
UPPER OCEAN WORKSHOP, HELD TIMBERLINE LODGE, OREGON - 3-5 MARCH--ETC(U)
APR 80 M C GREGG N00014-75-C-0502
UNCLASSIFIED APL-UW-TN-3-80 NL

1 OF 1
AD A
095518

END
DATE
FILMED
3-81
DTIC

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

AD A095518

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER 580	2. GOVT ACCESSION NO. AD-A095 518	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Upper Ocean Workshop, Summary Report		5. TYPE OF REPORT & PERIOD COVERED TECHNICAL REPORT
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) M. C. Gregg		8. CONTRACT OR GRANT NUMBER(s) N-00014-75-C-0502
9. PERFORMING ORGANIZATION NAME AND ADDRESS UNIVERSITY OF WASHINGTON DEPARTMENT OF OCEANOGRAPHY SEATTLE, WASHINGTON 98195		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS PROJECT NR 083-012
11. CONTROLLING OFFICE NAME AND ADDRESS ONR BRANCH OFFICE 1030 EAST GREEN STREET PASADENA, CALIFORNIA 91106		12. REPORT DATE 1980
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

DTIC ELECTE FEB 20 1981 D

18. SUPPLEMENTARY NOTES

C

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Upper ocean
Atmospheric forcing

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Approximately 30 academic physical oceanographers interested in observational programs in the upper ocean met for informal discussions from 3-5 March 1980 at Timberline Lodge, Oregon. The emphasis was on ideas for future research, including that work concerned with the direct response of the upper ocean to atmospheric forcing.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

3&80

Upper Ocean Workshop

Timberline Lodge, Oregon - 3-5 March 1980

Summary Report

APL-UW-TN 3-80
April 10, 1980

Prepared by:
Michael C. Gregg
Applied Physics Laboratory - University of Washington - Seattle, Washington 98105

CONTENTS

SUMMARY

Approximately 30 academic physical oceanographers interested in observational programs in the upper ocean met for informal discussions from 3-5 March 1980 at Timberline Lodge, Oregon. The emphasis was on ideas for future research, including that work concerned with the direct response of the upper ocean to atmospheric forcing. Since most of the investigators who took part in MILE and JASIN are now planning further observations in the upper ocean, the meeting began with short presentations in which the participants outlined their new projects. Following this there were discussions of some major questions concerning the upper ocean; these were pursued in smaller groups as well as by the full workshop. Finally, the proposed observational programs were considered again since many of the participants recognized opportunities for cooperation. This summary report has been prepared as a reminder for the participants and to provide a synopsis for others interested in upper ocean work.

The most significant conclusion to emerge from the meeting was that observational capabilities in the upper ocean are improving rapidly. New instruments made possible the MILE and JASIN programs, and now a second generation is being developed, including some for the purpose of upper ocean work during storms. Important discoveries have resulted almost every time new instruments have been used, and more can be expected. Since most of the investigators using these tools are studying particular processes, e.g., internal waves, intrusions, or small-scale mixing, their observational approach is to do joint programs to obtain those complementary measurements that are most directly necessary to understand the processes of interest. Until these immediate linkages are understood, the benefit to be gained from additional even larger programs is secondary. As an example, microstructure work has reached the point where the dissipative quantities χ and ε must be related to the local shear. Until this is done the relationship of the mixing events to mesoscale eddies or direct wind forcing is secondary; restricting the observations to only those large-scale experiments that can define the eddy field will not yield progress consistent with the effort involved.

The programs presented by the participants extend until 1984 in some cases. Much of the work is exploratory, reflecting the fact that our knowledge is severely restricted by the lack of any observations that define whether particular processes are important in even one situation. The diversity of the programs indicates that the question of which processes are important is a statistical problem and must be addressed at many times and places. Several of the efforts are of the same scope as MILE.* Compared with the effort in the upper ocean five years ago, this represents a large increase in the total effort and in the cooperation between individual research programs.

In short, rapid progress is being made in our understanding of the upper ocean and, although continued and even enhanced communication and cooperation will be beneficial, a significantly different way of working together, or a major new community-wide experiment is not warranted at this time.

In the following, the summaries of the presentations and discussions are grouped into scientific questions, instrumentation, and observational programs.

GENERAL SCIENTIFIC QUESTIONS

1. It was generally agreed that we still have much to learn about the mechanisms by which momentum, heat and chemical constituents are transferred at the sea surface and within the mixed layer.

   Very near the surface, which itself is poorly defined, we need to improve our understanding of how surface waves effect momentum exchange and how much of the Ekman transport may be carried by them. The presence of bubbles and spray may significantly affect transport of scalar properties but we do not yet know how to observe this.

*The Mixed Layer Experiment (MILE), which took place in August-September 1977, involved 14 principal scientists from 6 institutions, and some $1.5 million in funding, including analysis. It was conceived in 1975, and the major scientific papers began to appear in 1979.

Within the mixed layer we are still ignorant of the dominant sources of energy for mixing and of the structure of the turbulence. In generating turbulence, what is the relative importance of wave breaking and production by shear near the surface, in the interior of the layer, and at the base of the mixed layer? If waves are dominant, one would hope to observe microstructure and turbulence modulation related to breaking events. If surface shear is dominant, a dependence of turbulence on wind stress but little wave breaking modulation is expected. If shear at the mixed layer base is critical, then turbulence would be modulated by the shear at the bottom of the mixed layer that is more closely related to the relative phases of inertial motions above and below the mixed layer base than to wind stress. If turbulence production within the layer is important, a dependence of microstructure on internal shear and the Monin-Obuhkov length is expected. Observations that give evidence of several of these sources have been reported; however, there is insufficient evidence to determine under what situations different sources are dominant.

The need for vertical profiles of temperature and velocity microstructure as indicators of the location of turbulent energy sources in the column is great. Few measurements of this type have been made within 10 m of the surface during even moderate winds because present instruments behave poorly under such conditions, particularly during launch. The need for two- and three-dimensional cuts through the mixed layer on various scales was also emphasized. These are essential to define any large scale structures (Langmuir cells, convection plumes, shear instability billows, etc.) important in the mixing process, and to define the lateral intrusive processes that are observed when horizontal inhomogeneities relax. Similarly the "roughness" of the base of the mixed layer is believed to be important in generation of internal waves, and the structure of the near surface "micro-bubble cloud" discloses features of the turbulence near the surface. As an example of this strategy, Thorpe has monitored the bubble cloud in Loch Ness using

an acoustic sounder and found that (a) the bubble cloud depth varied almost linearly with wind speed, showing dependence of the turbulence on wave-breaking or near-surface shear, (b) bubble cloud depth did not respond to Langmuir cell slicks, suggesting that the cells are restricted to only a few meters depth or are very weak, and (c) distinct forms of roughness in the cloud's roughness corresponded to periods of convection, wave breaking and large shear.

2. Several points of particular concern for models of mixed layers were discussed. The goal was to pose observational questions that would test major assumptions of different models. In large measure the subjects of concern to modelers parallel the interest of the observationalists.

A. Is the deepening of mixed layers controlled by a critical Richardson number across the interface at the bottom? (This is a key assumption in Mellor's model.) Or, is the deepening related more closely to the wind stress, as supposed in models of the Kraus-Turner sort?

B. How should the flux from the seasonal thermocline into a stationary mixed layer be parameterized? By gradient diffusion?

C. How should the energy-containing turbulent components be parameterized? Some models use an integral length scale to describe the energy-containing motions, and this in turn forms the basis for parameterizing ε, the rate of dissipation of turbulent kinetic energy. Large-scale models assume that the integral scale depends upon latitude. Some of the observationalists felt that the dependence of models on an unknown integral scale was more a modeling convenience than something that could be related to measurements.

D. How does kinetic energy leave the mixed layer? Can the rate of decay of inertial energy in the mixed layer be reconciled with the downward flux of near-inertial energy in the

thermocline? Or is it possible that the energy leaks out as high frequency internal waves generated by mixed layer turbulence?

E. Are there significant two- and three-dimensional phenomena in the mixed layer? If so, what are they and how may their effects be parameterized?

F. Do frontal dynamics (e.g., convergence zones and jets) strongly alter mixed layer dynamics?

3. What is the importance of flows below the surface mixed layer? Two aspects of such flows were considered. The first concerned the role of Ekman divergence (convergence) on mixed layer dynamics. This has been incorporated into models, but never observed. If it is important, what are the time and length scales? Closely coupled to this is the general role of bulk Ekman dynamics. Over what space and time scales is it relevant? The second aspect of deeper flows was the role of intrusions, which have been observed directly at the base of the mixed layer as well as throughout the upper ocean. Are they major factors in the response of the ocean to atmospheric forcing, or are they more occasional happenings?

4. Motions of tidal and near-inertial frequency dominate the spectra of moored time series. What are the mechanisms for generating these motions and what are their spatial scales? The near-inertial motions are believed to have scales on the order of 100 km or more in the mixed layer, which are established by atmospheric forcing. (This is not well established, however.) The scales observed below the mixed layer are more on the order of 10 km. Why the difference? Do the shorter scales "leak out" more effectively? How do the leakage rates depend upon the depth of the mixed layer and on its three-dimensional structure? Briscoe pointed out that strong harmonics and mixing of the tidal and inertial signals are found in records from the upper ocean but not in those from several

kilometers deep. Are the harmonics smeared by nonlinear interactions?

5. Although not restricted to the upper ocean and atmospheric forcing, there was considerable interest in improving our understanding of the nature of small-scale vertical mixing in the seasonal and main thermocline. Measurements of temperature microstructure indicate that the gradient heat flux is quite low in the main thermocline but can be large in the seasonal thermocline beneath strong storms. These measurements are a very limited sample in space and time. Much more information needs to be obtained about the seasonal and geographical variability. It is also important to determine how χ and ε are related to the variability in the shear field. What effect do the dissipative events have on the internal wave spectrum? Are critical layers as important in the ocean as in the atmosphere? Or is most of the energy lost from the internal wave field in bottom and side wall boundary layers?

6. The transition from the mixing layer to the upper thermocline is a region of strong shear and intense gravity wave activity which continues into the thermocline. Many questions remain unanswered about the interaction of internal waves in shear flows. Is the internal wave directional spectrum affected by propagation of waves in a shear? How does this process affect wave-wave scattering, mixing and Reynold's stresses? How does the critical layer phenomenon actually operate in the presence of large amplitude waves with a continuous spectrum? A large part of the short-scale vertical shear is associated with quasi-inertial oscillations. How do high frequency internal waves interact with these time-dependent shears? Is there evidence for mixing events and transfer of momentum associated with critical layers?

INSTRUMENTAL DEVELOPMENTS

The capability of making observations of structures and motions in the upper ocean has increased greatly in recent years and was the basis for the MILE and JASIN programs. (The vector-measuring current meters developed by Weller and Davis may be available commercially by late 1980.) The next steps are the development of long-term upper ocean moorings (Halpern and Briscoe are both working on these), and the further development and refinement of towed and profiling instruments that can work efficiently in heavy sea states.

During the past year Sanford and Drever completed development of an expendable velocity profiler (XTVP) that produces data of quality comparable to their large EMVP. Osborn and Lueck are working on an expendable ε profiler using the shear foil probes that were successful on CAMEL. Miyake has been testing XCTD probes that are being produced commercially. Caldwell and Dillon at OSU and Oakey at Bedford have developed lightweight tethered profilers for microstructure in the upper ocean. A refinement of the OSU probe can be dropped and retrieved from a ship underway at 6-7 knots. Gregg and Lahore are developing an automatic profiler for temperature and velocity microstructure and density finestructure that can be deployed under strong storm conditions. In an effort to measure ε directly to the surface, Osborn's new internally-recording instrument will record data during its ascent.

Two other profiling systems are being developed which are probably not suitable for strong wind forcing but will work in the upper ocean under moderate conditions. Cox is completing a drifting yo-yo electromagnetic velocity profiler, which he calls the Cartesian Diver. It will have its first trial next autumn. It has a maximum depth of 1 km and will usually be operated between the surface and several hundred meters. The vertical water velocity will be determined by recording the rotation induced by paddles on the case as the vehicle rises (similar to the approach of Voorhis). Sanford and Gregg are developing a multiscale profiler (MSP) that combines the electromagnetic velocity data with an acoustic current meter and temperature, salinity and velocity microstructure information. The instrument will operate in the upper 1 to 1.5 km and can be used in moderately heavy sea states.

The ability to do horizontal measurements is also increasing. Paulson's towed thermistor chain was used to depths of 90 m during the FRONTS cruise. He plans to add conductivity cells and possibly other sensors. Gregg is studying the dynamic response of temperature and conductivity probes in an effort to improve the horizontal mapping of temperature and salinity with the APL-UW depth-cyling towed body. He also intends to add an O_2 sensor.

Osborn and Gargett are developing turbulence instrumentation for use on the USS Dolphin. The measurements include velocity, salinity, temperature and acceleration. They anticipate that observations can be made close to the surface and that the ship can be a component of future mixed layer programs.

Pinkel's development of remote probing of the near-surface velocity field from FLIP is being extended so that he can search for patterns in mixed layers. Using one sonar beam, the velocity can be sensed to a precision of ~1 $cm \cdot s^{-1}$ after 30 seconds averaging.

McWilliams and Niiler are designing six surface drifters for deployment during STREX in October 1980. A 120 m-long cable with 10 thermistors and 3 pressure sensors will be suspended below the floats, which will house atmospheric pressure and oceanic near-surface temperature. The data will be transmitted via satellite, providing 3 hour means and variances.

OBSERVATIONAL PROGRAMS

The observationalists discussed their plans for future work, which in some cases was foreseen to about 1984. Many of the plans involved cooperative endeavors of varying size; in some cases other participants indicated a desire to join the work. The following summaries describe the joint programs and do not include the solo investigations that were discussed. These projects are either funded, proposed, or "at the tip of the pen." Two additional themes emerged--studies of near-inertial motions and of deep convective mixed layers--in which many participants expressed strong interest for future cooperation. The table at the end indicates the estimated times of the programs.

1. STREX. Atmospheric scientists are planning measurements at Station P in the autumn of 1980 to examine air-sea transfers under storm conditions. Several oceanographers would like to participate in what are basically independent measurements-of-opportunity. The McWilliams and Niiler drifters have already been mentioned. Sanford has requested funds to deploy his XTVP to determine whether there is an increase in near-inertial storms. A highly energetic structure (a peak amplitude of 0.5 $m \cdot s^{-1}$ at 200 m depth) found north of Hawaii suggests the range of intensity of these features is not known. Also, deSzoeke would like to deploy four moored thermistor chains to examine convectively-dominated mixed layers during STREX.

2. FLIP-based observations of the near-surface velocity field will be made by Pinkel and Weller in May 1980 off Southern California. The acoustic Doppler system will be used to examine near-surface internal wave propagation and the directional spectrum of the near-surface internal wave field. Current and CTD profiles will be used to form the gradient Richardson number. The effect of FLIP's drift will be monitored using LORAN-C navigation. At the end of their observations, Sanford will take several patterns of XTVP profiles for an intercomparison and to examine the structures with scales greater than the range of the acoustic beams.

3. In mid-1982 or 1983 Pinkel, Weller, and Price plan to concentrate on structures within mixed layers, including some biological measurements. Attempts will be made to study the horizontal structure of the velocity field within mixed layers, including Langmuir and convective cells. It was suggested that Thrope's use of bubbles as tracers might be fruitful. It also might be advisable to direct the beams at a sufficient angle to the vertical to obtain a Doppler component from the stronger vertical motions in any cells.

Other investigators who expressed interest were Gregg, Osborn, and Sanford, who could base their yo-yo or expendable profilers on FLIP and use the acoustic signals for background. Osborn

and Gargett were interested in possibly operating the USS Dolphin nearby. Pinkel encouraged other measurements that could examine horizontal structures around FLIP.

4. Chris Mooers stressed the need to test the various numerical models (including those that will be used for operational forecasts) of the upper ocean thermal structure against common data sets. (Atmospheric scientists have found such prediction experiments beneficial; so probably will oceanic scientists.) He envisioned a program that would include repeated AXBT patterns, as well as current and wind measurements, to obtain multiple realizations of the evolution of forced events. This prediction experiment (PREDEX) could incorporate process studies of Ekman pumping/suction and near-inertial motion radiation; i.e., a comprehensive study of the ocean's adjustment/response to atmospheric forcing by storms and larger scale, larger term forcing. This experiment could commence in one-to-three years.

5. Briscoe emphasized that the next stage in long-term studies of the upper ocean is the deployment of near-surface moorings for several seasons to obtain adequate statistics based on multiple forcing events. He has proposed that such a mooring be established at 32°N, 57°W for a period of two years, beginning in late 1981. The site was chosen to provide occasional mesoscale forcing as well as direct wind events. A need exists for some more detailed measurements near the moorings on an occasional basis; this is also an opportunity for those wishing to use the moored data as background for their observations.

6. Niiler underscored the deeper response of the ocean to divergences and convergences in the shallow atmospherically-forced flow. He is preparing a proposal to study the low-frequency circulation of the Northeast Pacific. This would involve the installation in the summer of 1981 of two densely instrumented subsurface moorings along 150°W at 29°N and 42°N. Based on

the results of the first one-year deployment, larger arrays would be installed for up to two years. Specific moorings to study the upper ocean would be added for shorter periods.

7. Gregg and Sanford expressed their intention to explore signals in microstructure and near-inertial motions under strong storms. Gregg's motivation is the observation of Cox numbers changing from 6 to 1000 and back to below 10 as a storm passed over the MILE site. Sanford stressed the structure found in January 1980, which contained about 100 times the kinetic energy of the typical near-inertial feature; he believes that the feature was generated by the strong storms that had recently passed through the site. They will try to use ships of opportunity to explore the conditions under strong forcing events.

The above programs have their principal effort directed toward the direct response of the ocean to atmospheric forcing events. Several others are concerned with the upper ocean but have at most an indirect connection to atmospheric forcing.

8. Terry Joyce described the Warm-Core-Ring Experiment which has been proposed as a multidisciplinary program involving biologists and chemists as well as physical oceanographers. The objective is to examine contained systems having strong lateral gradients. The interaction of rings with the shelf water is also of interest. In the center of the rings, mixing processes are believed to be primarily vertical. Within the rings mixed layers are 20 to 30 m deep in summer, deepening to 350 m in winter, while in the slope water outside the rings the mixed layer depth is only 150 m. Lateral variability in these layers will be examined with CTD to-yo's. Several participants at the workshop suggested that this promises to be an opportunity to examine a unique mixed layer regime and should be viewed in the larger context of convectively-driven mixed layers; measurements should be made that can be repeated in the deep mixed layers south of the Gulf Stream.

On the edges of the rings, the many thermohaline intrusions found in the upper 300 m suggest that lateral mixing is dominant, which gives rise to the question of why the rings live so long. A series of to-yo's is planned to obtain statistics of intrusions through the boundaries.

Osborn plans to obtain ε profiles in the rings. Joyce expressed a need for temperature microstructure measurements and more detailed horizontal observations than can be obtained with to-yo's.

Leaman plans to deploy a Cyclesonde, and Gregg and Sanford said they expected the MSP to be ready for the 1983 program.

9. The Subtropical North Atlantic Gyre Experiment was described by Schott as being focused on the main thermocline near 26°N in the Western North Atlantic. The goal is to observe low-frequency variability, e.g. the changing amplitude of the Antilles Current. Moored current meters will be placed in the zone from 100 m to 1000 m, and the vertical velocity will be inferred assuming the Beta Spiral.

10. Several investigators expressed interest in further measurements in the Equatorial Undercurrent. Hayes and Halpern are now doing so as part of EPOCS. The PEQUOD program is trying to develop an upper-ocean program; as part of this, Pinkel is considering taking FLIP to the equator and letting it drift for nearly a month to examine the generation of internal waves in the strong shear zone. This would be done in either 1983 or 1984. Gregg is planning to use the microstructure yo-yo, and Osborn expressed interest in using his expendables.

11. Gregg discussed a plan to examine the transport of scalar quantities from the seasonal thermocline into the mixed layer under the trade winds. In these locations the observed microstructure levels have been far lower than would be expected from the gradient fluxes required to sustain the standing crop

observed by biologists. The yo-yo will be used to obtain an extensive set of microstructure measurements following a tagged water parcel. Davis expressed interest in releasing a cluster of floats instrumented with temperature, and possibly conductivity, sensors.

12. Following the meeting Chip Cox provided the following summary of his proposals for future observations.

A. *Experiments on measuring the spatial structure of currents (frequency < coriolis frequency)*

(1) The goals are to describe the fine scale of currents in the surface mixed layer and in the thermocline. Frontal systems at the surface and intrusions at depth are examples of structures that have smallish scales of the currents. Fronts can also exist below the surface--for example, the formation of intrusions from unique surface conditions. Some of the questions to be asked are:

(a) What are the cross-sectional scales of these flows? Do the flows form a filamentous structure? What are the meander forms? What time scales are involved?

(b) How are small-scale flows maintained? Is there interaction with internal waves that tends to accentuate or diminish small-scale structure? What are the shears (vertical, horizontal) in the flow and how do they interact with internal waves and currents?

(2) Techniques needed to attack these questions are continuous in nature because discrete observations with fixed current meters cannot (unless very closely spaced) avoid aliasing spatial scales. Examples of continuous shear recorders are the EMVP of Sanford, the Cartesian Diver (both vertical profilers) and the Doppler devices of Pinkel and Regier (mixed horizontal, vertical profilers). An experiment with

these devices should be accompanied by CTP observations in a close spaced network and probably with moored current meters for reference information.

B. *Stormy weather and its influence on internal motion*

(1) So far in the study of near surface properties of the ocean it has not been possible to evaluate the relative influence of storm events vs long-term less intense conditions for establishing the mean climatology of the ocean as a whole. In particular some questions which badly need answers are:

(a) How is the internal wave climate maintained? Is it supplied by energy in bursts which then supports the calm weather internal wave energy by spreading widely through the ocean? What is the energy flux into internal waves in stormy conditions? Does this locally enhance wave energy with associated dissipative events? How much wave energy can escape from the stormy region? How deeply does it penetrate into the sea?

(b) By what amount are dissipative events enhanced by enhanced internal wave and other shear flows? What is the role of inertial oscillation in these processes? How deeply does the dissipation extend? How much turbulent transport of properties is brought about by these processes? Can storm-generated events provide the "missing" eddy fluxes which have been inferred from chemical measurements of average mixing?

(2) Techniques that can be applied to these questions must be capable of operation under stormy conditions. Our experience has so far been unsuccessful (mostly) for these extremes, but efforts are under way in two directions. (a) Expendable probes launched from shipboard may be practical. (Question: how do we avoid having a connecting link to ship blown back in our faces by wind?) (b) Probes and moorings that can be launched and recovered between storms may be successful (moored C.M.'s certainly are). The Cartesian Diver is intended to work in this way.

C. The mutual influences of quasi-steady shear flows, internal waves, and turbulence need to be examined. If shear flows can produce some types of anisotropy in internal wave spectra, this should lead to rapid momentum fluxes. Strong shears may lead to critical layers from certain internal waves. If formed, these are important influences on the shear flow itself, on the internal waves and on mixing. Some questions are (a) what is the degree and type of anisotropy of internal waves in shear flows? Is there a measurable Reynold's stress? What is the interaction of high frequency internal waves with shear of strong, short vertical wavelength inertial oscillation? (b) Do critical layers develop in these or in steady shears? What is the nature of nonlinear interactions in shear flows? Does this interaction tend to reduce the importance of critical layers? What is the nature of dissipative processes in critical layers? How does the critical layers phenomenon affect the spectrum of internal waves in the neighborhood of shear flows? (c) Does shear instability develop in the absence of critical layers because of instability of intense internal waves?

These and related questions require new observations combined with the best theoretical work to guide experiments and to help explain the results. The development over the past several years of shear probes such as the EMVP and Cartesian Diver and Doppler sonar will provide some of the required tools.

D. Some other processes that interest me and are not described above are the following:

(a) What is the nature of the sharp and regular stair step profile in the vertical which only occasionally appears, but has been described several times? Sometimes, but not always, it seems to be the signature of a double diffusive process.

(b) How does the internal wave energy in the deep water manage to maintain itself almost at a constant level? What about diffusion of internal wave energy vs radiative transport? What is the degree to which the I.W. spectrum on equilibrium or quasi-equilibrium form?

Discussion was begun of two observational programs that were of interest to many people attending the workshop--Near-Inertial Motions and Deep Convective Mixed Layers. Some of the scientific questions concerning near-inertial motions have already been discussed. Further consideration is expected. Sanford suggested a special session at the Fall AGU, which Mooers agreed to organize.

Most of the attention that has been given to mixed layer experiments has been concerned with wind-forced events. Many think that convectively-dominated regimes merit investigation, especially since these are the source of most of the intermediate water. Some of the particular questions raised were: Is it possible to measure latent heat flux from a buoy? Is the dissipation really different in a convectively-dominated regime? What is a first-order description of the horizontal structure in such a regime?

Joyce and Briscoe pointed out that Worthington is planning an investigation of the Gulf Stream and the transport of the 18° water for 1982 and 1983. Observations of the deep convective mixed layers south of the Stream would complement that work. Mooers suggested the Texas shelf as an alternate site, due to the frequent, strong "northers" there and the subsequent outbreaks of cold air. Since the probability of finding a convectively-driven deepening event is low during any 3-week cruise, Briscoe offered to consider moving his proposed mooring to this site if there was sufficient interest. Further discussions are expected. There was also interest in whether any of the proposed drilling sites for the Glomar Explorer would provide a good location for extended profiling measurements.

Table I. Observation Programs for Which Dates (Firm or Tentative) Have Been Set

	1980	1981	1982	1983	1984
STREX	X				
FLIP - Seasonal Thermocline	X				
FLIP - Mixed Layer			X		
FLIP - Equatorial Undercurrent					X
Briscoe - Atlantic Moorings					
Niiler - Pacific Moorings					
Warm-Core-Rings					
Subtropical N. Atlantic Gyre					

WORKSHOP PARTICIPANTS

U.C., San Diego

Russ Davis
Charles Cox
Rob Pinkel
Steve Thorpe - Visitor
Thomas Osborn - Visitor

Oregon State University

Peter Niiler
Clayton Paulson
Thomas Dillon
Roland deSzoeke
Murray Levine

Woods Hole Oceanographic Inst.

Melbourne Briscoe
Terrence Joyce
James Price
Robert Weller
Douglas Caldwell - Visitor
Lynne Talley - Student
Eric d'Asaro - Student

Naval Postgraduate School

Chris Mooers
Roland Garwood

NASA

Larry McGoldrick

University of Washington

Thomas Sanford
Michael Gregg

PMEL - Seattle

David Halpern
Stan Hayes

NCAR

James McWilliams

University of Miami

Fritz Schott
Kevin Leaman

Nova University

Pijush Kundu

Pat Bay Ocean. Lab.

Ann Gargett
Michael Miyake

ONR

Lou Goodman

APPENDIX

In preparation for the meeting, most of the participants prepared one page summaries of their personal research goals. Two participants elected to include their summaries here.

SOME HIGHLIGHTS OF PERSONAL INTEREST: from the modeling viewpoint

Roland William Garwood, Jr.
Department of Oceanography, Naval Postgraduate School

I. Spring Transition in the Oceanic Planetary Boundary Layer (OPBL)

Fig. 1 shows a model climatology (17-year mean) for the variance in mixed layer depth at a site in the North Pacific. The largest variance is in the late winter, and there is a very rapid reduction in the month of April. The peak value in March is associated with year-to-year variability in the time of spring transition. This result further (Elsberry and Garwood, 1978:Bull. Am. Meteorol. Soc., 59) emphasizes the importance of the March and April air-sea interaction in temperate latitudes. Future field and modeling programs should recognize the significance of this time period during which the ocean is most sensitive to variations in atmospheric forcing. In addition to the annual and longer-scale climatic implications, the spring transition has significance for the survival of fish larvae (Lasker, 1978: Rapp. P.-v. Reun. Cons. int. Explor. Mer, 173).

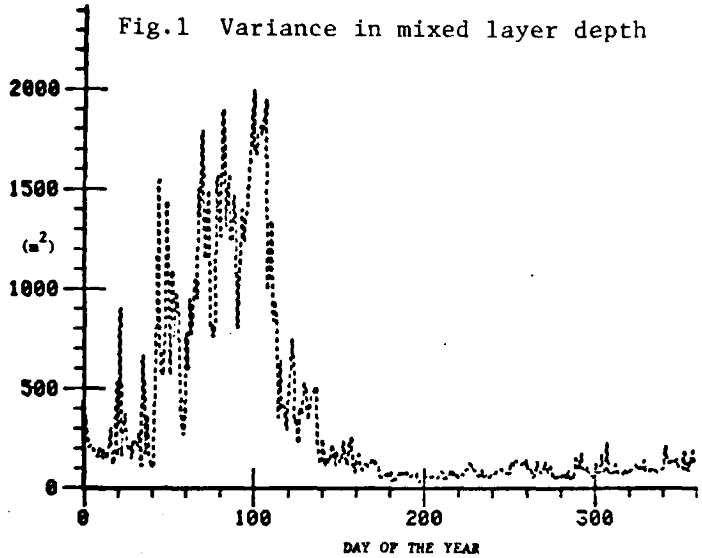

Fig.1 Variance in mixed layer depth

II. Surface Density Fronts

Interaction between frontal circulation and OPBL processes are being studied with the aid of a new coupled OPBL-General Circulation Model (Adamec, et al, 1980: in prep.). Initial results suggest that wind direction relative to the local frontal azimuth and stratification due to surface heating are important in determining cross-frontal mixing and upwelling and downwelling circulations at the interface between water masses. Fig. 2 shows T(x,z) sections under combinations of heating and wind direction conditions after 12 hours.

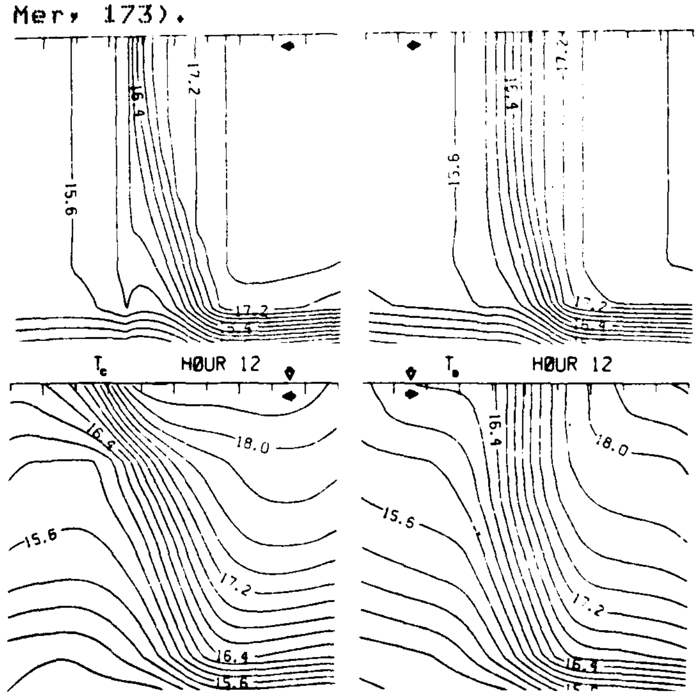

Fig. 2 Model results with identical initial conditions. Open arrows show direction of net surface heat flux, and closed arrows give direction of Ekman transport. Horizontal tick marks are at 5 KM spacing, and the vertical scale is 50 M overall.

<u>Brief Statement of Upper Ocean Research Plans</u>

Christopher N. K. Mooers
Department of Oceanography
Naval Postgraduate School

The general topic of interest is the prediction of upper ocean thermal structure and all that implies. The ability to make a short range (few days), limited area (10^4 km^2) forecast of the field of mixed layer depth and temperature, to some as yet undefined accuracy, in a general oceanic region would be significant. The basic questions are: "How do you do it? and "How do you know when you have done it?" Component questions of interest include:

a. How "good" do the atmospheric forcing data have to be? Some sensitivity tests would be needed.
b. How well can they be determined from satellite or other remote sensing? Is an atmospheric model needed to make a good estimate?
c. Can we use satellite or other remote sensing data, together with climatology and geostrophic and Ekman dynamics, to make an initial analysis?
d. Given the initial analysis and some estimates of boundary conditions, and forecasts of atmospheric forcing, do we have an upper ocean thermal structure forecast capability <u>or</u> are we limited by our ability to parameterize transfer processes, initialize, or verify?

Sometimes, it is interesting to contemplate a series of prediction experiments. You probably would like tests under storm conditions. Quickly, there would arise the question of anyone's ability to resolve spatially the atmospheric forcing induced by a storm without a storm model.

A more specific problem of strong personal, professional interest is the theory of the generation of near-inertial motions by atmospheric forcing, their propagation (especially in oceanic frontal zones), their role in mixing via the shear instabilities they may induce, and parameterization of any such turbulent mixing. Results from several studies, apparently including FRONTS, lend some vitality to this avenue of investigation.

Another topic of very strong interest to me is the interaction of the eddy stream of the California Current, irregular coastal bathymetry, and the sequence of synoptic disturbances (weather cycles) of the Northeast Pacific with the West Coast upwelling regime, which presumably leads to offshore entrainment in the upper layer of upwelled waters so provocatively and seemingly apparent in satellite IR imagery.

One can also wonder about the California Current System. For example, what-in-the-world are its three traditional seasons: upwelling, oceanic, and Davidson Current? How do the waters and flow of the California Current, Undercurrent, and Countercurrent "tie-in" with the general circulation of the North Pacific, especially considering the hints now available regarding intra-annual and interannual variability in all components of the System? Are mesoscale coastal wind systems of importance to evolving the state of the oceanic upper layer? In the coastal ocean? Elsewhere?

1 March 1980